

DR SATYAMAANASA POLUBOTHU (Orcid ID : 0000-0001-7195-5670)

DR VERONICA A KINSLER (Orcid ID : 0000-0001-6256-327X)

DR NEIL N RAJAN (Orcid ID : 0000-0002-5850-5680)

Article type : Research Letter

A mosaic variant in *MAP2K1* is associated with giant naevus-spilus type congenital melanocytic naevus and melanoma development

S. Muthiah,^{1,2*} S. Polubothu,^{3,4*} A. Husain,⁵ T. Oliphant,² V.A. Kinsler^{3,4+} and N. Rajan^{1,2+}.

1. Institute of Genetic Medicine, University of Newcastle upon Tyne.

2. Department of Dermatology, Royal Victoria Infirmary, Newcastle upon Tyne.

3. Paediatric Dermatology, Great Ormond Street Hospital for Children NHS Foundation Trust, London, United Kingdom.

4. Francis Crick Institute, London, UK

5. Department of Cellular Pathology, Royal Victoria Infirmary, Newcastle upon Tyne.

Corresponding author: Neil Rajan

Email: neil.rajan@newcastle.ac.uk

^{*,+} Equally contributing authors

Conflict of interest statement: The authors declare no conflicts of interest.

Keywords: melanoma, *MAP2K1*, naevus spilus – type congenital melanocytic naevus, cutaneous mosaicism

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the [Version of Record](#). Please cite this article as [doi: 10.1111/BJD.19118](#)

This article is protected by copyright. All rights reserved

Giant congenital melanocytic naevi (CMN) arise primarily due to postzygotic mutations in *NRAS*, and are of clinical importance due to their increased risk of malignant transformation.¹ A subtype of large CMN, termed naevus spilus (NS)-type CMN, is identified by the presence of a patch which may have café-au-lait pigmentation and superimposed macular or papular lesions, which are demonstrably melanocytic naevi on histology. We present a patient who developed three melanomas within a NS-type CMN affecting the entire left leg, where a pathogenic variant in the Ras signalling pathway gene *MAP2K1* was identified.²

A 43-year-old female presented with a superficial spreading malignant melanoma (SSMM) on the left medial thigh, with a Breslow thickness (BT) of 0.6mm. A clinical decision for excision was made as it was distinct from other naevi on the leg. Two further melanomas were identified on the left lateral foot (Figure 1) and left lateral thigh, reported as lentiginous malignant melanoma (LMM), BT 0.3mm and a LMM with complete regression of the dermal component, respectively. The unilateral presentation was not associated with background café-au-lait pigmentation, however it was apparent that there were many more dark naevi on the affected limb compared to the rest of the patient's skin, suggesting cutaneous mosaicism.

Following patient consent, DNA was isolated from two of the melanomas and the NS-type CMN on the left thigh and analysed using targeted next generation sequencing of a panel of pigmentation related genes³ with a median on target fold coverage of >1000x. A missense substitution at codon 203 in *MAP2K1* (c.607G>A, p.E203K) was identified within both melanomas (medial left thigh and left lateral foot) and also within the background NS-type CMN. Allele loads were 7% in the SSMM, 2% in the LMM, and 1% in the NS-type CMN. A second variant in *MAP2K1* (c.308T>A, p.I103N) was also seen in the SSMM (7% allele load), but undetectable in the other melanoma and NS-type CMN. Targeted sequencing specifically excluded *HRAS*, *NRAS* and *BRAF* mutations in the NS-type CMN and melanomas.

NS-type CMN have previously been associated with specific mosaic variants in *NRAS*.^{1,2,4} Our patient differs phenotypically from prior cases and has many small, dark naevi on the skin of the affected limb with no apparent café-au-lait pigmentation. These naevi were not present at birth, and continue to develop. NS-type CMN are a clinically heterogeneous entity, and our finding of a postzygotic mutation in *MAP2K1* adds to known

existing drivers such as *NRAS*.⁴ The *MAP2K1* E203K variant lies within the protein kinase domain of the *MAP2K1* protein. This results in a gain of function at the protein level; E203K mutated melanoma cell lines demonstrate constitutive phosphorylation of ERK, a downstream kinase in the Ras signalling pathway⁵. Importantly, similar mutations in the germline give rise to cardiofaciocutaneous (CFC) syndrome, which has been associated with increased numbers of melanocytic naevi, adding support for the pathogenicity of this variant.⁶ Furthermore, *MAP2K1* mutations have been found in up to 6% of cases in series of melanoma.⁵ Mosaic *MAP2K1* variants have recently been described as a cause of arteriovenous malformations,³ but not previously in melanocytic lesions. Taken together, our findings suggest that our patient's NS-type CMN is driven by a postzygotic mutation in *MAP2K1*, predisposing to development of melanoma within the lesion. It is of interest that a second pathogenic variant in *MAP2K1* (p.I103N) was detected in one melanoma at an identical allele load. It hints at the possibility that biallelic mutations in *MAP2K1* are important to initiate melanoma formation in this birthmark. It would be of interest to determine if loss of heterozygosity of *MAP2K1* has occurred specifically in melanoma cells in this patient's remaining melanomas, however technical issues relating to working with paraffin embedded tissue prevent this from being demonstrated unequivocally. Our findings highlight the clinical and genetic heterogeneity in NS-type CMN. These data add evidence to the central role of Ras signalling in CMN and melanoma development, and the need for long-term follow up of such patients.

Acknowledgements This work is funded in part by Melanoma Focus. VK is funded by Wellcome grant WT104076MA. NR's work was supported by a Wellcome Trust funded Intermediate Clinical Fellowship WT097163MA. NR's research is also supported by the Newcastle NIHR Biomedical Research Centre (BRC) and the Newcastle MRC/EPSRC Molecular Pathology Node.

Figure Legends

Figure 1: (a) NS-type CMN involving the entire left leg and left suprapubic region, presenting as unilateral increased melanocytic naevi and melanoma; (b) Close up of the SSMM arising on the left thigh (indicated by the white dotted circle and inset image), within the confines of the LSN; (c) Close up of another melanoma arising on the left lateral foot, (indicated by white dotted circle and inset image), within the confines of the LSN. (d) Histology of the melanoma from the left thigh (original magnification 20x; H+E, white scale bar=100 μ m).

References

1. Krengel, S. *et al.* Naevus spilus-type congenital melanocytic naevus associated with a novel NRAS codon 61 mutation. *Br J Dermatol* **174**, 642-4 (2016).
2. Schaffer, J.V., Orlow, S.J., Lazova, R. & Bolognia, J.L. Speckled lentiginous nevus: within the spectrum of congenital melanocytic nevi. *Arch Dermatol* **137**, 172-8 (2001).
3. Al-Olabi, L. *et al.* Mosaic RAS/MAPK variants cause sporadic vascular malformations which respond to targeted therapy. *J Clin Invest* **128**, 1496-1508 (2018).
4. Martins da Silva, V. *et al.* Genetic Abnormalities in Large to Giant Congenital Nevi: Beyond NRAS Mutations. *J Invest Dermatol* **139**, 900-908 (2019).
5. Nikolaev, S.I. *et al.* Exome sequencing identifies recurrent somatic MAP2K1 and MAP2K2 mutations in melanoma. *Nat Genet* **44**, 133-9 (2011).
6. Siegel, D.H., McKenzie, J., Frieden, I.J. & Rauen, K.A. Dermatological findings in 61 mutation-positive individuals with cardiofaciocutaneous syndrome. *Br J Dermatol* **164**, 521-9 (2011).

Figure 1

